MOBILE TELECOMMUNICATIONS NETWORK
WITH IMPROVED DOWNLINK CAPACITY

Cross Reference To Related Application

This application claims priority of European Patent Application No.

5   00307844.1, which was filed on September 11, 2000.

Background of the Invention

1. Field of the Invention

This invention relates to a mobile telecommunications network with improved downlink capacity, especially to a GSM (Global System for Mobile communications)

10   network employing Space Division Multiple Access (SDMA) techniques.

2. Description of the Related Art

In a GSM system in which the network is arranged as a series of contiguous cells, each served by a base station with a single antenna, the objective is to improve the trade-off between quality of service, i.e. minimum interference between calls, and

15   maximum number of users. The common approach to reduce interference is to permit only one user in a cell, or, since cells are divided into three 120 degree sectors, to permit only one user in a sector, but this restricts the number of users. When each cell or sector is supplied with a number of radio channels, permitting only one user per radio channel per sector provides some increase in capacity.

20   When multiple antennas are employed at the base station of each cell, a beamforming scheme is applied in the downlink. Multiple users in the same cell or cell sector can be allocated on the same radio channel. For each user a beam is formed which "steers" the transmitted power towards the appropriate direction. This approach is known as Space Division Multiple Access (SDMA).

25   A spatial channel allocator is proposed by P Zetterberg and B Ottersten in "The Spectrum Efficiency of a Basestation Antenna Array System for Spatially Selective Transmission", IEEE Trans. Vehicular Technology, Vol. 44, pp.651-660, August 1995. This technique assumes the knowledge of all directions associated with the mobiles present, and assigns the spatial channels so that mobiles operating on the

30   same channel have maximal angular separation. However, in a multi-path environment, knowledge of all directions is unrealistic, and in the presence of large angular spread the directions-of-arrival estimation may fail completely.

Further, in circumstances in which two mobile users are initially separated by an acceptable angular distance in the same sector, it may be the case that by movement of one or both mobiles, the angular distance is reduced so that the beams become unresolvable. In effect the users are now inseparable and unacceptable levels

5   of interference occur.

Summary of the Invention

It is the object of the invention to provide an arrangement in which angular unresolvability of two co-channel mobile users is prevented.

According to the invention a method of operating a mobile

10   telecommunications network, the network having a multiplicity of contiguous telecommunications cells, comprising providing directional beams for a plurality of mobile users in the same telecommunications cell or sector of a cell and on the same telecommunications channel; characterized by monitoring the carrier-to-interference ratio for each user; comparing the monitored values with a threshold value; and when

15   the threshold value is reached by a user, allocating a different telecommunications channel to that user.

Also according to the invention a base station for a mobile telecommunications cell sector comprising a plurality of antennae; beamforming means to provide a plurality of directional beam patterns on the same

20   telecommunications channel; and receiving means arranged to receive spatial information from every mobile user served by the base station; characterized by spatial allocation means arranged to store a threshold value of carrier-to-interference ratio; to monitor the carrier-to-interference ratio for every mobile user served by the base station; to compare the received values to the threshold value and, when the

25   threshold value is reached for a mobile user to allocate a different telecommunications channel to that mobile user.

Brief Description of the Drawings

In the drawings, Figure 1 illustrates five hexagonal cells of a GSM system. The invention will be described by way of example only with reference to Figures 1

30   and 2 in which:

Figure 2 illustrates the use of two directional beams in the same sector of a telecommunications cell; and

Figure 3 illustrates a mobile telecommunications system base station.

Detailed Description of the Invention

5   Figure 1 illustrates five hexagonal cells C1 to C5, each divided into three 120 degree sectors, such as sectors 10, 12, 14 in cell C4. In a cellular system such as the GSM system, it is known that in the downlink, sectors of the cells employing the same frequency channels interfere, for example, assuming 1/3 frequency reuse pattern, sectors C4A and C5A of cells C4 and C5 cause interference to the users in sector C1A

10   of cell C1, while sector C1A causes interference to users in sectors C2A, C3A of cells C2 and C3.

The use of directional beams alleviates the problem of interference in the downlink, by efficiently transmitting power toward the desired directions, compared to the omnidirectional transmission with a single antenna.

15   One such directional beam is shown in sector C1A of cell C1; the beam has a major lobe 16 in the required direction and relatively small side lobes 18. This alleviates intracell interference by directing the power to a required mobile.

Figure 2 illustrates the use of directional beams in more detail. In Figure 2A, a hexagonal telecommunications cell C10 is divided into three sectors 20, 22, 24 having

20   a base station BS for each sector. Within sector 20 there are two mobile users MU1 and MU2. The base station BS generates directional beams 26, 28 in the same channel, one to each user. MU1 and MU2 are well separated and the beams have a substantial angle between them.

In Figure 2B user MU2 has moved so that the angle between the beams has

25   decreased substantially. In Figure 2C, user MU2 has moved so that the angle between the beams 26, 28 is now very small; MU1 and MU2 are in effect within the main lobe of each beam, the beams are inseparable and considerable interference results between the mobile users.

In the invention, the CIR (Carrier-to-Interference Ratio) of both users is

30   monitored. As the interbeam angle decreases, the CIR also decreases. A CIR

threshold is set and when the CIR of one MU reaches the threshold, that mobile is allocated to a different radio channel.

       In a simulation, assume that there are N_C cells in a cluster and three 120 degree sectors in each cell. Each sector uses either the whole radio spectrum allocated to
5   each cell (S=1) or one third of the spectrum (S=3). If there are U co-channel users in the same cell sector, the Spatial Division Multiple Access capacity C_{SDMA} can be defined as $C_{SDMA} = \dfrac{U}{N_c x S}$.   (1)

       Considering a typical urban GSM radio environment as set out in GSM 05.05, version 5.10.0, 1996, the stochastic geometry-based channel model is described by J
10 Fuhl, A F Molisch, and E Bonek in" Unified channel model for mobile radio systems with smart antennas", IEE Proc. Radar, Sonar & Navig., Vol.145, No.1, February 1998 can be used for the analysis. The cells have a radius of five km and the base station at each sector employs a uniform linear array of N antennae with half a wavelength inter-element spacing.

15   In the CIR calculations, only the first ring of interfering cells is considered, e.g. for 1/3 frequency reuse pattern cells C2, C3, C4 and C5 in Figure 1. The path loss exponent is 4 and the standard deviation of the log-normal shadow fading distribution is 6dB. It is assumed that the speed of all mobile users is 50km/h. A maximum number of 6 handovers, i.e. six allocations of a mobile to a different channel, is
20 allowed.

       The objective is to optimize the trade-off between C_{SDMA} and quality, with quality being characterized by the probability of an outage, P_{out} where:-

$P_{out} = Pr(CIR < CIR_{thr})$.   (2)

       The threshold is set as 9dB.

25   Two approaches to optimizing the trade-off can be taken, fixed capacity and optimized capacity.

       In the fixed capacity approach, the number of SDMA co-channel users U is kept fixed and the objective is to improve quality for each user. This is illustrated in Table 1 in which :-

N = the number of antennae

Reuse = Frequency Reuse pattern

U = number of users in a sector

C_{SDMA} is calculated from Equation 1

5   CIR is calculated as 5% of the cumulative density function given in Equation 2

TABLE 1 – SPATIAL CHANNEL ALLOCATION STRATEGY FOR FIXED CAPACITY

N	Reuse	U	C_{SDMA}	$CIR_{5\%}$ (dB)
4	1/3	2	0.67	2
6	1/3	2	0.67	8.5
8	1/3	2	0.67	11
8	4/12	2	0.17	12.5
8	7/21	2	0.09	14.2

The achieved CIR is the measure of capacity enhancement. The improvement in CIR can then be traded for tighter reuse (smaller N_c x S) i.e. a more aggressive channel reuse, and therefore improved capacity.

10   In the optimized capacity approach, the maximal number of SDMA co-channel users is allocated on the same channel, subject to the constraint that the CIR of each user is higher than the pre-specified level, 9dB in the example. This is illustrated in Table 2.

TABLE 2 – SPATIAL CHANNEL ALLOCATION STRATEGY FOR OPTIMISED CAPACITY

N	Reuse	U	C_{SDMA}	$CIR_{5\%}$ (dB)
4	1/3	1.7	0.57	9
6	1/3	2.1	0.7	9.8
8	1/3	2.2	0.73	10.5
8	4/12	2.4	0.2	11

8	7/21	2.5	0.12	12

The achieved number of SDMA users is the measure of the capacity enhancement of this approach, i.e. an increased number of users in the same cell sector on the same radio channel. In effect, intracell co-channel interference has been mitigated.

5   Although intercell interference is taken into account in the above simulation results, no intercell interference mitigation scheme is employed. In order to further improve capacity, SDMA approach can be combined with an intercell interference mitigation scheme, the so-called Spatial Filtering for Interference Reduction (SFIR) approach.

10   It is to be understood that the adapted beam arrangement according to the invention does not require direction-of-arrival estimation, as set out in the prior art of Zetterberg, and is based on information sent from each mobile to its active base station; such information is a feature of GSM standards so that no modification of mobile equipment is required.

15   Referring now to Figure 3, which is highly schematic, a base station BS has a number of antennae 30 and contains a beamformer 32 and many other components (not illustrated). The basestation BS receives spatial information 34 for every mobile user MU and the beamformer directs a beam pattern towards each MU. Figure 2 shows two beams 26, 28 on the same channel as in Figure 2 directed towards MU1
20 and MU2.

The received spatial information 34 is available on the uplink. For application of the present invention, the uplink information is expressed in the form of covariance matrices corresponding to the channel response vectors between each user and the antenna array.

25   As is provided for in GSM specifications, the MUs send information 36 to the BS about their CIR status and, in a base station according to the invention, this CIR information is directed to a spatial allocation circuit 38. Circuit 38 contains a preset CIR threshold and the CIR information from each MU is compared with this

threshold. When the CIR, e.g. of MU2, falls before the desired level because it has approached MU1 too closely for beam separation, the circuit 38 instructs the base station to allocate MU2 to a different channel and informs the beamformer of the different set of mobile users now sharing the same channel, so that the appropriate

5   beam patterns are generated. The channel originally allocated to MU2 can now be allocated to a different mobile in the same sector, but at a greater angular distance from MU1. If the new arrangement does not satisfy the CIR threshold, re-allocation is instructed until the condition is satisfied or a maximum number of re-allocations is reached.

10   Application of the invention does not require any modification to a mobile system and requires only a small additional feature to each base station. The CIR threshold can be under the control of the network operator.

By preventing the development of a situation in which two mobile users become inseparable so far as directional beams are concerned, use of the invention

15   results in an improvement in the trade-off between SDMA capacity and CIR.